A Scoring System for Certification and Interlaboratory Comparison of QC Test of SPECT

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Abstract-**A scoring system was designed for certification and QC test on basis of NEMA standards and clinical requirements on SPECT. According to the functions of SPECT the scoring system was presented three parts: planar, whole body scan and tomography. The marks in the scoring system were given in accordance with normalized parameters of QC tests. We used scatter phantom and some simulated methods to change system performance to its rationality.**

I. Introduction

A scoring system was designed on basis of QC standards and clinical requirements [1] [2]. According to the functions of SPECT the scoring system was presented three parts: planar, whole body scan and tomography. The score of planar performance is the key parameters to assess the system condition and to judge whether the system has to be stopped to use or be scrapped. The whole body scan performance is on basis of the score of planar plus the score of whole body scan and the tomographic performance is on the score of planar plus the score of tomography. The marks in the scoring system were given in accordance with normalized parameters of QC tests. The normalized parameters were values of QC test divided by the original technical specifications of system. The scoring weights were modified to reduce effects of improper factors and to improve adaptability of the scoring system. Only some necessary parameters of QC were put in the scoring system to increase its practicability. We used scatter phantom and some simulated methods to change system performance to its rationality. In the scoring system we paid more attention to its rationality and made it easy to perform.

The certification of QC on SPECT is in two parts: 1) Acceptance test, it is performed when a new system is installed. The specialist will take a rigorous test according to the items listed on the contract. The specifications given by manufacturers will be a reference to evaluate the quality of the system. In acceptance test two situations will be appeared on every item only, pass or not. It means the score will be 1 (pass) or 0 (not pass) and the total score will equate to the number of testing items. If one testing item dos not pass the acceptance test is failure. 2) Certification test, it is an examination for every SPECT system in medical centers before the annual permission is issued. Three situations will be met: normal, need maintenance and stop using. In study of the certification project we found that judging by the results of QC was very difficult to decide which system would be passed the certification test, or would be stopped using to be repaired, or had to be scrapped. The scoring system will give a quantitative levels to judge what will be done for medical center and authorities of certification.

II. Method

According to the functions of SPECT the scoring system presented three parts: planar, whole body scan and tomography. The score of planar performance is the key parameters to assess the system condition. The whole body scan performance is on basis of the score of planar plus the score of whole body scan and the tomographic performance is on the score of planar plus the score of tomography. Because of different systems may be produced by different vendors in different ages the marks in the scoring system were given in accordance with normalized parameters of QC tests. The normalized parameters were the values of QC test minus the technical specifications then divided by the technical specifications which were given by the manufacturers (1).

$$V_n = \begin{cases} (V_{QC} - V_{ts})/V_{ts} & (V_{QC} - V_{ts}) \geq 0 \\ 0 & else \end{cases} \quad (1)$$

Where V_n is the normalized parameter, V_{QC} is value of QC test and V_{ts} is the technical specification.

In some QC tests (such as sensitivity and maximum count rate) the worse performance will be lower values so that the normalized parameters were the technical specifications minus the values of QC tests then they were divided by the specifications (2).

$$V_n = \begin{cases} (V_{ts} - V_{QC})/V_{ts} & (V_{ts} - V_{QC}) \geq 0 \\ 0 & else \end{cases} \quad (2)$$

Where V_n is the normalized parameter, V_{QC} is value of QC test and V_{ts} is the technical specification.

And also we set up values of the worst level. If any parameter of any system is worse than the worst level it would mean that this system had to be stopped using. In addition, we ranked the effects of QC parameters influenced performance of system and clinical images. We gave higher weights to more important parameters, such as uniformity of

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Abstract

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CFOV and intrinsic resolution. The scoring weights were modified to reduce effects of improper factors and to improve adaptability of scoring system

A. Planar Score

A certain level of QC test is required to prove that the gamma camera is functioning properly on clinic. We wanted to test minimum QC items to provide an evaluation of system performance. Six items were chosen: energy resolution, intrinsic uniformity, intrinsic resolution, intrinsic sensitivity, 20% window maximum count rate, emergency switch. In those testing items energy resolution, intrinsic uniformity and intrinsic resolution were more important than others. So we gave higher weights to them.

1) *Energy resolution:* Bad energy resolution or incorrect energy window setting will degrade uniformity, spatial resolution and sensitivity.

2) *Intrinsic uniformity:* The uniformity is one of the most basic and important QC test on the gamma camera system. Uniformity defects will be caused by a failure of PMT, incorrect HV, incorrect energy window setting and inappropriate corrections. The system uniformity is important for SPECT system so that it has to be tested with every collimator used in clinic to compare with intrinsic uniformity. The results of comparisons will indicate whether collimators are uniformity or not. But in the scoring system we gave marks to intrinsic uniformity only.

3) *Intrinsic resolution:* The resolution is a sensitive and important parameter relating to clinical diagnosis. A loss of resolution may be caused by energy peak shifting, incorrect window setting, inappropriate adjustments carried out during service or some problems of hardware. Intrinsic resolution is easier to perform with 4 quadrant bar phantom. However, it does not test resolution including effect of collimator. It is necessary to test system resolution on every collimator used in clinic.

4) *Other items:* Intrinsic sensitivity is not in NEMA Standard [1] but it is given by manufacturers. If sensitivity of gamma camera is degraded one or more problems may happen, such as incorrect window setting, HV shift, PMT problem, crystal problem, etc.. Again the system sensitivity has to be tested on every collimator used in clinic. 20% window maximum count rate indicates the effect of dead time of detector to limit acquiring counts in high count rate. Lower maximum count rate may cause by problems of electric circuit, aging of crystal or PMT, coupling of crystal and PMT [3,4]. Emergency switch is very important to prevent patients and operators to be hurt by the equipment in accident. It has to stop main power supply reliably when the switch is pushed down. It is only item not necessary to be normalized.

B. Whole Body Scan

Only whole body scan resolution was chosen in the scoring system for whole body scan. The whole body scan resolution may be affected by planar performance, or both mechanical problems and drift, or inappropriate adjustment of image offset or size. Normally manufacturers did not list specifications of whole body scan resolution. By experience the whole body scan resolution is about 15% worse than system resolution so we normalized to the value of 1.15 times system resolution given by manufacturers.

C. Tomography

We chose tomography resolution as the scoring item to test tomography performance [5]. The radius of rotation and collimator in test is same as in test of system resolution. The testing result will show the status of the SPECT system, such as high count uniformity correction, center of rotation offset, proper timing in rotation and reconstruction software. As same as whole body scan, the manufacturers would not list specifications of tomography. The tomography resolution is about 10% worse than planar system resolution so the value of 1.1 times system resolution given by manufacturer will be used to be normalized to.

D. Scoring

According to NEMA Standard and IAEA TECDOC-602 [2] the QC tests described above were performed. The values of testing results were normalized in percentage. They were divided into five ranks: 0~10%, 10~25%, 25~50%, 50~80%, more than 80%. Every rank has its own score, shown in table I. The different weights were given to different testing items, shown in table II. The mark for every test is weight times score, shown in table III.

TABLE I.
SCORES OF FIVE RANKS

Rank	0≤>10%	10≤>25%	25≤>50%	50≤>80%	80%≤
Score	4	3	2	1	0

TABLE II
THE WEIGHTS OF QC ITEMS

Energy Res.	Intrinsic Res.		Intrinsic Uniformity				Sens.	Max. Count Rate	Emerg. Switch	Whole Body Res.	Tomo Res.
			UFOV		CFOV						
	UFOV	CFOV	Integ.	Differ.	Integ.	Differ.					
4	2	3	2	2.5	2.5	3	2	2	*	10	10

* The emergency switch was not given weight.

TABLE III
THE FULL MARKS OF QC ITEMS

Energy Res.	Intrinsic Res.		Intrinsic Uniformity				Sens.	Max. Count Rate	Emerg. Switch	Whole Body Res.	Tomo Res.
			UFOV		CFOV						
	UFOV	CFOV	Integ.	Differ.	Integ.	Differ.					
16	8	12	8	10	10	12	8	8	8	40	40

The full mark for planar is 100, for whole body scan and for tomography is 140. If the mark in one part (ex. In whole body scan) is lower than 50% of full mark or the mark of one item in planar is zero the system has to be stopped using. If only the mark of whole body scan resolution is zero this part will be stopped using, or if only the mark of tomography resolution is zero the tomography will be stopped using.

E. Testing Phantom

We designed simple phantom or simulated method to degrade specifications of system.

1) *Scatter phantom:* We made several polymethyl plates that were 2cm thick and same area as the detector face (or larger than detector face). The polymethyl plates were put on detector face one by one. Intrinsic resolution was tested with different thickness of scatter plates and the results are in table IV. The serial number and direction were marked on every plate. The certain plates were used to take whole body scan to simulate different resolutions for volunteers.

2) *Changing detector distance:* Detector distance or radius of rotation will affect sensitivity and resolution in tomography imaging. Planar and tomography resolutions were tested in different distances for 10~35cm (in table V).

3) *Changing energy window setting*: If energy window setting is shifted the system performance will be degraded. We shifted window setting to simulate bad performance of system to test QC parameters. In different simulated conditions we took QC phantoms and volunteer studies. To shift window setting will cause bad uniformity and lower sensitivity. In low sensitivity condition it should take long time to get enough counts.

TABLE IV
INTRINSIC RESOLUTIONS WITH SCATTER PLATES OF DIFFERENT THICKNESS

Scatter (cm)	0	2	4	6	8	10	12
FWHM (mm)	3.74	4.25	5.41	6.51	7.66	8.84	10.02
FWTM (mm)	7.21	8.44	10.96	13.38	15.83	18.49	21.77

TABLE V
SYSTEM RESOLUTIONS IN DIFFERENT DISTANCES

Distance (cm)	10	15	20	25	30	35
Planar Res. (mm)	8.07	8.55	9.20	9.77	10.29	10.63
Tomo Res. (mm)	8.85	10.37	12.52	15.77	19.63	24.69

III. DISCUSSION

1) The performances of collimators were not included in our scoring system so that the giving marks will present a full picture of intrinsic performances of testing camera. The performances of collimators will not be changed by its aging so only one collimator used in clinic will be chosen in the tests of whole body scan and tomography resolution.

2) We tested the performance of SPECT system and effects of clinical images in our center with scatter phantom and simulating models. On studies we found that some items that had been listed in scoring system before made repeat scoring and some weights that had been given were not proper. The items that took repeat effects were deleted and modified the weights to make whole system to be reasonable.

3) The best way to prove the scoring system is comparison of the marks and clinical studies. It is difficult to take clinical studies in different conditions of SPECT system for one volunteer. Instead of that we took clinical studies in different conditions for different volunteers.

4) For dual-head system every detector has to be scored. The scoring principles as same as single head system.

5) In the scoring system we did not consider some kinds of hardware troubles, such as crystal broken. We did not include the quality of formatter and film processor but they are very important in clinical imaging.

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